Europäisches Patentamt | European Patent Office | Office européen des brevets

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

02077668.8

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02077668.8
Demande no:

Anmeldetag:
Date of filing: 05.07.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

Koninklijke Philips Electronics N.V.
Groenewoudseweg 1
5621 BA Eindhoven
PAYS-BAS

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Magneto-optical data storage medium with antiferromagnetically coupled domain-expansion double-layer structure

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G11B11/00

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

Magneto-optical data storage medium with antiferromagnetically coupled domain-expansion double-layer structure.

The invention relates to a magneto-optical data storage medium comprising a magneto-optical recording layer and an auxiliary magnetic layer wherein a reproduction signal is reproduced by magnetically transferring a recorded magnetic domain of the magneto-optical recording layer to the auxiliary magnetic layer upon irradiation with reproducing light, whereby a larger magnetic domain than the recorded magnetic domain of the magneto-optical recording layer can be read back from the auxiliary magnetic layer at the time of reproduction by virtue of the magnetic characteristics of the auxiliary magnetic layer

Magneto-Optical storage offers the advantage over Phase-Change recording that marks with a dimension well below the diffraction limit can be written and readout. In MO recording these small bits are written by using Laser Pulsed Magnetic Field Modulation. In LP-MFM the bit transitions are determined by the switching of the field and the temperature gradient induced by the switching of the laser. For readout of the small crescent shaped marks recorded in this way one has to use Magnetic Super Resolution or Domain Expansion methods. These technologies are based on media with several magnetostatic or exchange coupled RE-TM layers. A readout layer on the disk masks adjacent bits during reading (MSR) or expands the domain in the center of the spot (DomEx). The advantage of DomEx over MSR is that bits with a dimension well below the diffraction limit can be detected with a similar SNR as bits with a size comparable to the diffraction limited spot. Magnetic Amplifying MO System (MAMMOS) is a DomEx method, proposed by H.Awano et al. *Appl. Phys.Lett.* vol. 69, no. 27 pp. 4257-4259, Dec. 1996, which is based on a magneto-statically coupled storage and expansion layer. Domain Wall Displacement Detection (DWDD) is a method based on an exchange coupled storage and readout layer, proposed by T. Shiratori et al. in *Proc.* MORIS'97, *J. Magn. Soc. Jpn.*, 1997, vol. 22, supplement no S2, pp. 47-50.

The storage and (super-resolution) readout layers applied in Magneto-Optical storage are based on Rare-Earth Transition-Metal alloys like TbFeCo and GdFeCo. These layers are ferrimagnetic with opposite magnetization directions of the RE and TM sublattices.

Often the composition is chosen in such a way that a perpendicular magnetic anisotropy is obtained. By depositing two RE-TM layers on top of each other they can be easily exchange coupled. The lowest energy state is usually the state in which the sublattices in both layers have the same orientation. However, when one layer is RE-rich and the other TM-rich the net magnetziation in the two layers will be opposite. This (direct) exchange coupling of RE-TM layers and the magnetostatic coupling of RE-TM layers over a non-magnetic dielectric layer forms the basis of all known superresolution technologies in MO recording.

For ferromagnetic thin-films also antiferromagnetic or ferrimagnetic behavior can be obtained by coupling two ferromagnetic thin-films over for instance a thin non-magnetic Ru layer. This effect is well known and is applied for biasing GMR and TMR elements in sensors and MRAMs. The use of antiferromagntic coupling of ferromagnetic storage layers for Hard Disc Storage is also known and applied in state of the art HDD products to increase the magnetic stability of the storage layers. In this case two ferromagnetic in-plane magnetized Co-alloy films are coupled antiferromagnetically over a Ru layer. In US patent 5.756.202 it has been described that antiferromagnetic coupling of two ferromagnetic perpendicularly magnetized (Co/Pt) multilayer stacks over e.g. a Ru layer can be used for superresolution and direct-overwrite MO recording.

The problems to be solved:

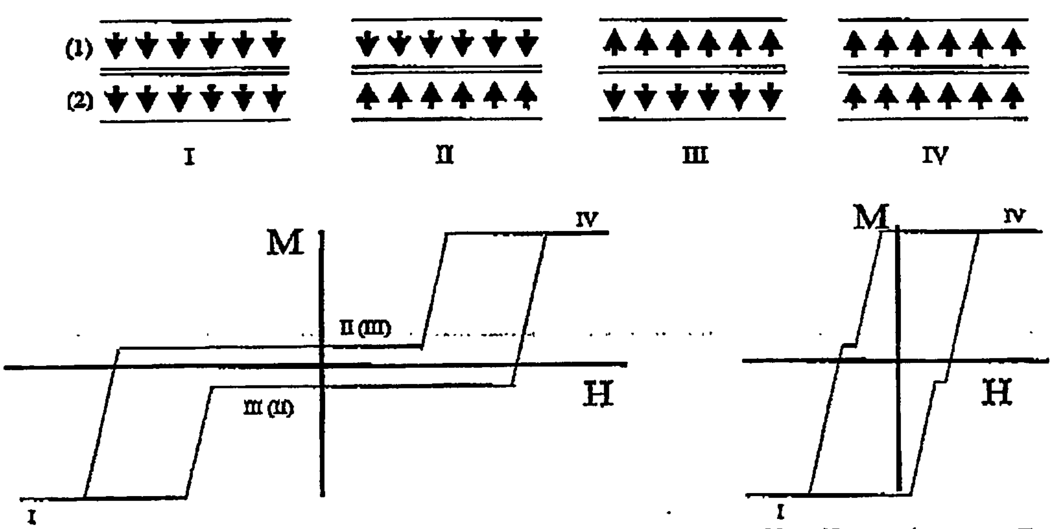
A number of MAMMOS readout schemes are known. Of these MAMMOS technologies RF-MAMMOS has been studied in most detail. In this method a uniformly perpendicularly magnetized readout layer is used. In the center of the readout spot heating leads to an enhancement of the stray field of the storage layer and a reduction of the coercivity of the readout layer. When the bit in the center of the spot has a magnetization direction opposite to the initial readout layer magnetization a reverse domain is nucleated in the readout layer. A modulated external readout field drives the domain expansion and subsequent collapse. This method has a number of disadvantages. During readout an exact timing of the readout field and position of the spot on the data on the disk is required. Furthermore, timing recovery from the data is not possible in the conventional readout scheme and read-power and field margins during high resolution readout are small. The recently proposed zero-field MAMMOS technology seems to solve the aforementioned problems. A readout field is no longer required and recording experiments indicate that margins are much larger. At the moment the physics behind zero-field MAMMOS is not clear.

An alternative improved MAMMOS technology to come to zero-field MAMMOS is desired.

Solutions, new insights, obtained advantages:

According to the invention it is proposed to use an antiferromagnetically (exchange) coupled double layer structure in the MAMMOS stack. For such a double layer structure with a perpendicular anisotropy four magnetization states can exist as denoted in the picture below by I, II, III, and IV. The state that occurs in a certain external field will depend on the balance of the antiferromagnetic coupling and magneto-static coupling strength as well as the magnetic hysteresis. In a sufficiently large external field the two layers will orient itself parallel to the external field and against the antiferromagnetic coupling (I and IV). In a small field the antiferromagnetic coupling dominates resulting in a anti-parallel state (II and III). When the coercivity is comparable to the exchange coupling field more complicated loops can arise in which not necessarily only states II and III occur in zero-field. When the strength of the AF coupling is reduced the loop will more and more resemble the loop of a single layer as shown by the loop on the right in the picture of Fig.6 below.

FIG.6



large AF exchange field small AF exchange field

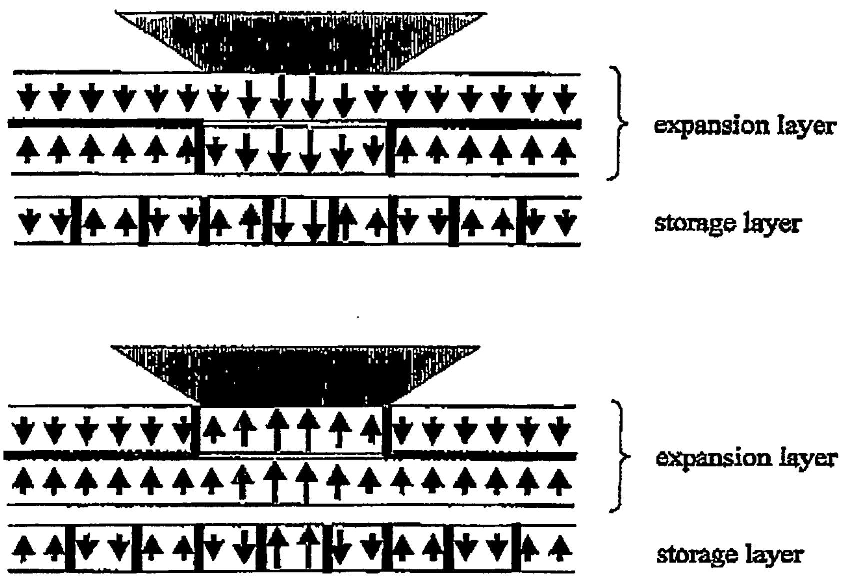
It can be easily derived that the switching field for the switching of layer i (i=1,2) is given by

$$H_{sw,i} = \frac{-2J}{\mu_0 M_i t_i} \pm H_{c,i}$$

where J is the antiferromagnetic coupling strength (J<0), and M_i, t_i and $H_{c,i}$ are the magnetization, thickness and coercivity of layer i. When no separate RE-TM (intermediate) coupling layer is used the exchange coupling strength generally does not show a strong temperature dependence. On the other hand, in RE-TM materials the magnetization can be

strongly temperature dependent when the compensation temperature is close to the temperature range of interest for MO recording. For instance, when the compensation temperature is close to room temperature and the Curie temperature above the readout temperature, the shape of the loop can easily change from the shape shown on the left to the shape shown on the right at the readout temperature.

FIG. 7



The picture of Fig. 7 above shows the net magnetization around the readout spot in the storage and AF-coupled expansion layer. It is assumed that the compensation temperature of both parts of the expansion layer is close to room temperature. In the readout spot the temperature is that high that the magnetostatic coupling in the double layer structure dominates the exchange coupling. This is indicated by the non-shaded area in the intermediate layer. If the coercivity of both layers is sufficiently low they will orient both in the direction of the increased stray field from the storage layer in the center of the spot. This orientation mechanism is similar to mechanism in a conventional MAMMOS medium. A main difference is however, that a completely symmetric behavior for both magnetization directions can (in principle) be obtained when both parts of the expansion layer have the same composition and magnetic properties. In that case they will expand in the same way and also the energy related to the walls in the expansion layer will be the same for both situations

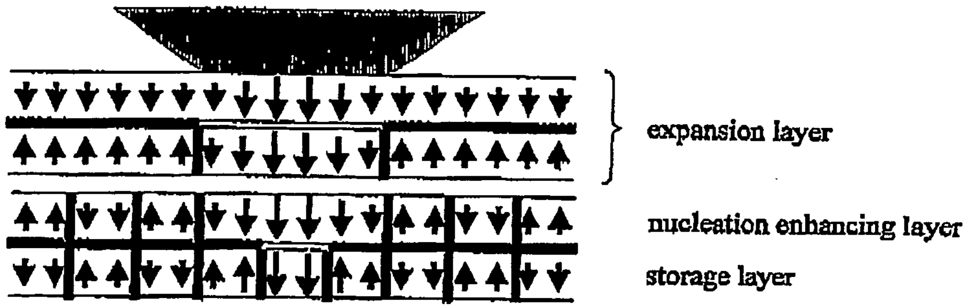
as shown above. Furthermore, demagnetziation energy is very small due to the anti-parallel orientation in the expansion layer outside the nucleated domain.

For RE-TM layers with a direct exchange coupling or with a coupling over a thin RE-TM intermediate layer it will be very difficult or perhaps even impossible to obtain the anti-parallel coupling with the two sublayers having the same composition. Therefore, it is proposed here to apply a thin *non-magnetic* metallic intermediate layer for this purpose. It is well known that e.g. a thin Ru layer inbetween Co or Fe films leads to a AF coupling when the thickness of the Ru layer has the appropriate value. The coupling behavior of Ru and various other metals has been studied in detail in combination with magnetic transition metal films like Co, Ni and Fe. As far as known, the behavior of RE-TM/ Ru /RE-TM films has not been studied. Because the RE-TM films used in MO media have a high percentage of Fe and Co the coupling behavior will resemble the coupling behavior in transition metal films. The application of a thin non-magnetic metallic coupling structures in RE-TM films will give an extra degree of freedom in designing superresolution media.

Besides (symmetric) nucleation, a zero-field domain expansion process also requires expansion without the help of an external field. A readout layer with a AF coupled double layer offers another source for the required outward force on the domain wall besides those already known and applied in MAMMOS and DWDD media. The increased temperature in the readout spot and by that the increased magnetostatic coupling in the double layer dominating the AF exchange coupling leads to this outward force. In practice it will be more complicated to arrive at this condition because the stray fields from the storage layer outside the central region as well as the temperature dependence of the wall energy will counteract the outward force.

A possibility exists to reduce the counteracting stray fields of the storage layer outside the central region by using a AF coupled double-layer storage layer based on the same principles as described above. This is shown in the picture of Fig. 8 below. In this case two layers are used with a TbFeCo composition close to the optimal composition for conventional disks. A thin layer of e.g. Ru is used as intermediate layer and the thickness is chosen such that the configuration of the magnetization in the double-layer is anti-parallel everywhere with exception only of the (most heated) central region of the spot. To assure that information is not lost during the reorientation process in the center of the spot it is advisable to chose the thickness of one layer slightly smaller than the other one so that this "nucleation enhancing" layer only reorients in the center of the spot and the magnetization in the other layer stays fixed.

FIG. 8



The layer structures described in this invention communication are meant for MSR and DomEx readout so for application in high density MO storage.

Embodiments:

Fig. 1 shows Kerr loops v. Ru thickness for a sample comprising a stack 20 nm SiN/ 15 nm TbFeCo / Ru / 10 nm TbFeCo / 20 nm SiN,

Fig. 2 shows Kerr loops v. TbFeCo thickness for a sample comprising a stack 20 nm SiN/ TbFeCo / 0.9 nm Ru / TbFeCo / 20 nm SiN,

Fig. 3 shows exchange coupling strength for a sample comprising a stack 20 nm SiN/ TbFeCo / 0.9 nm Ru / TbFeCo / 20 nm SiN,

Fig. 4 shows major and minor loop for a sample comprising as stack 20 nm SiN/ 15 nm TbFeCo / 0.9 nm Ru / 10 nm TbFeCo / 20 nm SiN,

Fig. 5 shows major and minor loop for a sample comprising a stack Glass/20nm SiN/15nm GdFeCo/0.9 nm Ru/ 10 nm GdFeCo/20nm SiN.

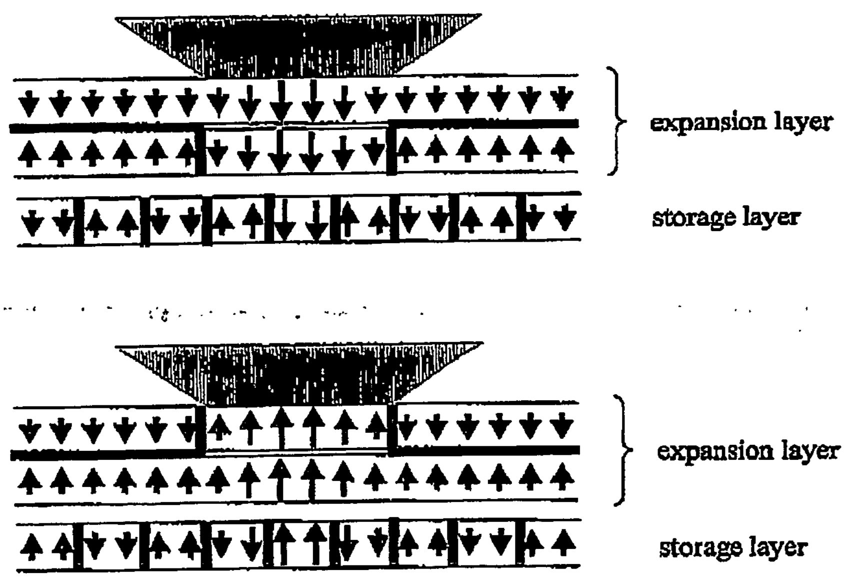
CLAIM:

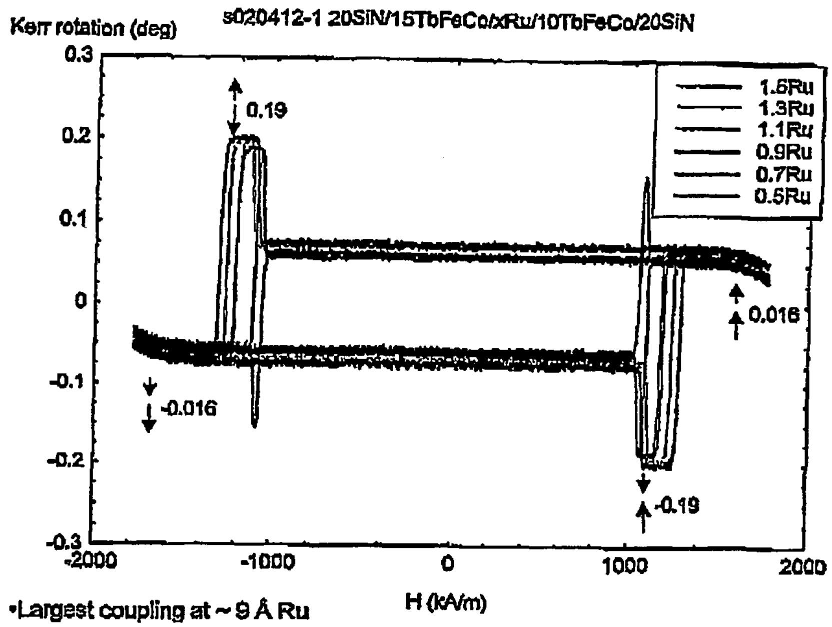
1. A magneto-optical data storage medium comprising a magneto-optical recording layer and an auxiliary magnetic layer wherein a reproduction signal is reproduced by magnetically transferring a recorded magnetic domain of the magneto-optical recording layer to the auxiliary magnetic layer upon irradiation with reproducing light, whereby a larger magnetic domain than the recorded magnetic domain of the magneto-optical recording layer can be read back from the auxiliary magnetic layer at the time of reproduction by virtue of the magnetic characteristics of the auxiliary magnetic layer, characterized in that the auxiliary magnetic layer comprises a stack including at least two sub-layers which are antiferromagnetically coupled through a non-magnetic metallic layer.

ABSTRACT:

It is proposed to use a readout expansion layer consisting of a double- or bilayer of antiferromagnetically layers, e.g. GdFeCo or TbFeCo, coupled over a relatively thin, e.g. < 2 nm, non-magnetic metallic layer, e.g. Ru. Under influence of the temperature rise by the focused spot of a read out radiation beam and the stray field from the storage layer the magnetization in the bilayer will switch from a antiparallel to a parallel state. A main advantage of this layer structure is that it offers a symmetric readout respons for up / down magnetization in the storage layer and can in principle be used without external readout field.

Fig. 7





•Largest coupling at ~ 9 Å Ru

•Switching delayed to opposite fields due to large H_c of TbFeCo

FIG. 1 TbFeCo/Ru/TbFeCo: Kerr loops v. Ru thickness

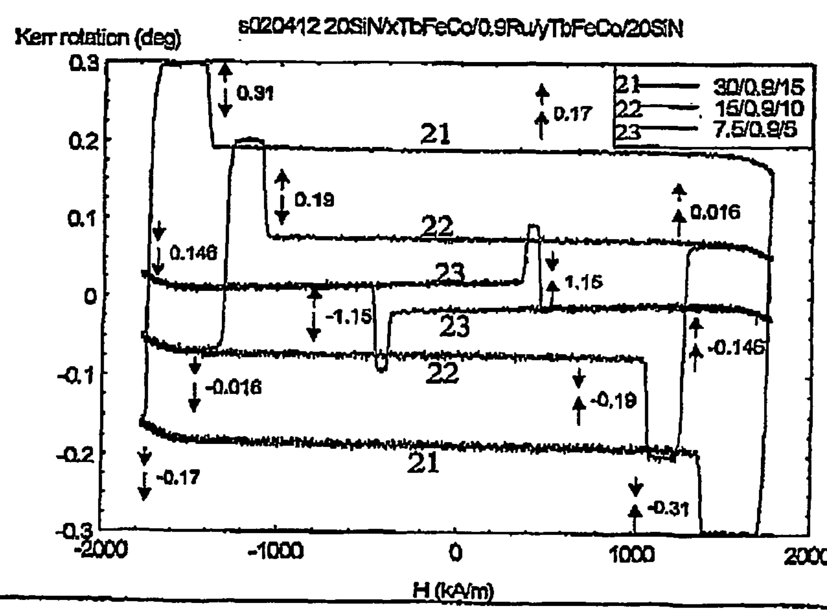
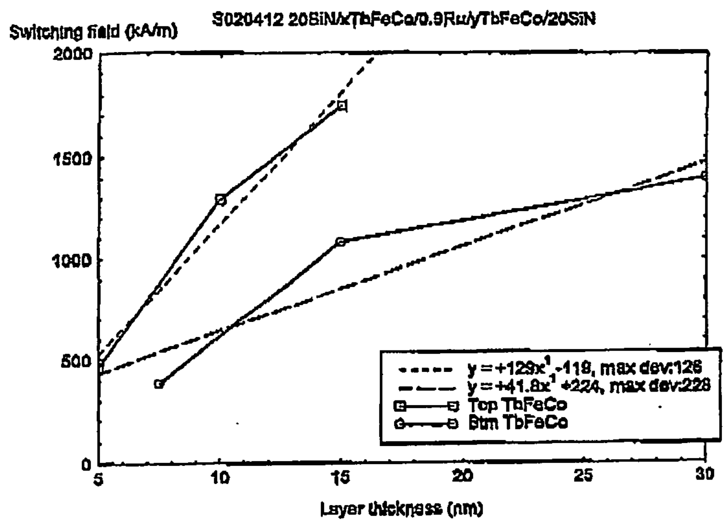
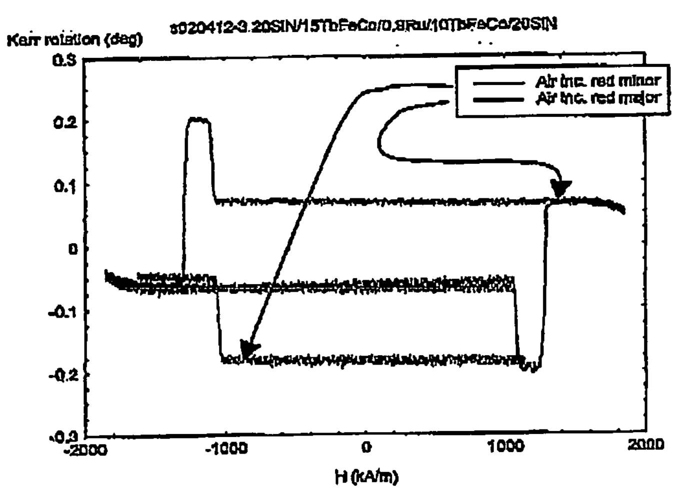


FIG. 2 TbFeCo/Ru/TbFeCo: Kerr loops v. TbFeCo thickness



- Switching field versus thickness gives AF coupling strength J=1.4 ± 0.8 mJ/m²
- similar magnitude as obtained for XMR stacks

FIG. 3 TbFeCo/Ru/TbFeCo: Exchange coupling strength.



- 2 parallel and 2 antiparallel "stable" states at zero-field

FIG. 4 TbFeCo/Ru/TbFeCo: Major and minor loop

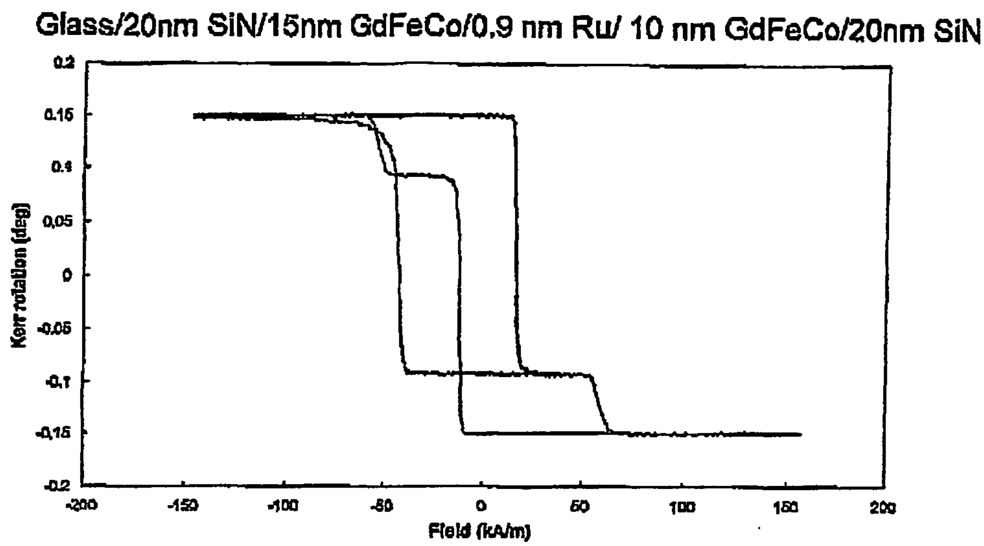


FIG. 5 GdFeCo/Ru/GdFeCo major and minor loop